mous number of bacteria present at times in ice-creams—one of the highest records being seven millions in one cub. cm. The sources of danger in ice-creams are obvious, as they come from the spoons and vessels, and the persons and dwellings of the street vendors.

Laboratory experiments have confirmed the conclusion that a freezing process is not necessarily fatal to bacterial life. We have instances of bacteria multiplying at zero, and of their survival after a six months' exposure to the temperature of liquid air. It is not therefore surprising that the American observers were unable to secure a complete sterilisation of bacterial cultures by the freezing methods they employed. The question became therefore a relative one. What was the probability or likelihood of infection through ice in the case of typhoid fever? It would appear that about 90 per cent. of the ordinary water bacteria are eliminated by the process of freezing. The authors find that, in the case of a specific pathogenic organism such as the *Bacillus typhosus,* less than one per cent. survive simple freezing for a period of fourteen days. Complete sterility did not occur even at the end of three months, whilst a process of alternate thawing and freezing, if on the whole more fatal to the typhoid germs than a simple freezing, was equally unsuccessful in effecting an absolute sterilisation of the infected water. The reduction in the number of typhoid bacilli in chilled water was approximately as great as occurred in ice. The process of destruction proved to be a continuous one, whether it occurred above or below the freezing-point, and whether the experiments were made in water or in soil. A progressive reduction in the number of organisms occurred to the extent of about 99 per cent., and proceeded *pari passu* with the duration of the experiment. Cold exercises a disinfecting action as regards the typhoid bacillus, and in natural ice there is a supplementary purifying influence to be taken into account, as, at the time of freezing, 90 per cent. of the germs are thrown out by a process of physical exclusion. These are the main conclusions arrived at, and the authors find that they are in accord with the general result of experience, namely, that natural ice can very rarely be a vehicle of typhoid fever.

The research may perhaps fairly be described as a study of the death-rate of typhoid bacilli under adverse conditions, as furnished by cold. The percentage mortality, as a matter of fact, is such as might occur under the influence of light, a poor food supply, and disinfectant agents generally. It is therefore permissible to think that the danger of infection in the case of ice, if it is minimised, is not by any means abolished. A certain number of typhoid bacilli, as the experiments show, do remain alive, and these may, on rethawing, undergo a rapid multiplication outside as well as inside the human body. And it has likewise to be remembered that it is notoriously difficult to trace the exact channels of infection in sporadic cases of typhoid fever. The infection has at times occurred from the most unexpected quarters.

Prof. Sedgwick and Mr. Winslow have rightly drawn attention to the unfavourable conditions furnished by natural ice for the propagation of the typhoid organism. It is at the same time feasible to assume that ice may likewise act as a conserving agent, inasmuch as the cold, whilst inhibiting the growth of the typhoid bacillus, will equally prevent the multiplication of other competitive forms of life.

The experiments do not affect the general question of the persistence of life at low temperatures. If the temperature be sufficiently low to produce a complete anæsthesia of the cells, cold tends to act as a conserving agent on the typhoid bacillus and allied forms.

It only remains to commend the memoir of Prof. Sedgwick and Mr. Winslow to the attention of all who are interested in the epidemiological questions involved.

ALLAN MACFADYEN.

NOTE ON THE PROBABLE OCCASIONAL INSTABILITY OF ALL MATTER.

AS a summary of my remarks at the discussion on Prof. Rutherford's most interesting communication on the subject of radio-activity to the Physical Society of London on Friday last, June 5, I beg to communicate the following:—

Consider an electron or other particle, of mass m and of negative charge e, revolving at speed u round the much more massive rest of an atom possessing an equal positive charge. The centripetal force between them is

$$\frac{mu^2}{r} = \frac{e^2}{\mathrm{K}r^2},$$

where the first r strictly is measured to the centre of gravity of the two bodies, and the second r is the distance between their centres; but taking these as usual practically equal for the lighter body, we get Kepler's law for the case

$$ru^2 = \text{const.} = \frac{e^2}{\mathrm{K}m} \quad . \; . \; . \; . \; . \; . \; (1)$$

Larmor has shown ("Æther and Matter," p. 227) that an electric charge subject to acceleration radiates some of its kinetic energy, though the radiation becomes of prominent amount only when the acceleration is great; as, for instance, when kathode rays are suddenly stopped by a target. The "power" of the radiation, or the energy lost per unit time, is

$$\mathrm{R} = \frac{2\mu e^2 \dot{u}^2}{3v} \quad . \; . \; . \; . \; . \; . \; . \; . \; (2)$$

where u is the acceleration of the electric charge e, and v is the velocity of light.

In the case of steady circular motion, the only acceleration is normal or centripetal, viz.

$$\dot{u} = u^2/r \quad . \; . \; . \; . \; . \; . \; . \; . \; (3)$$

but that is just as effective for radiation purposes as the tangential variety.

Hence, combining the three equations, we get, for the radiating power,

$$\mathrm{R} = \frac{2}{3\mu} \cdot \left(\frac{m}{e}\right)^2 \cdot \frac{u^8}{v^5} \quad . \; . \; . \; . \; . \; . \; . \; (4)$$

that is, a constant multiplied by the eighth power of the velocity of the rapidly moving particle: an expression which corresponds with what for ordinary molecular motions is known as Stefan's law, connecting radiation with temperature, *i.e.* with square of molecular velocity.

Now the radiation loss is equivalent to a resisting medium, and accordingly the revolving particle tends to move inwards towards its centre, and its speed to increase in accordance with equation (1). A slight increase in speed brings about a great increase in radiating power, as is shown by equation (4); wherefore the change, once appreciably begun, may be expected to go on rapidly, until presently the speed approaches the velocity of light. On the electric theory of matter, radiation or loss of energy must occur from every atom, and therefore it is only a question of time how long an atom shall last before it reaches this stage.

Directly this stage is reached another effect supervenes; the rapidly moving portion of the mass begins rapidly to rise in value, according to a complicated expression not yet quite fully worked out. This effect

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is unimportant until the speed comes very near to the light velocity, but the mass becomes suddenly infinite or very great when the light velocity is attained.

I find it difficult to realise the full effect of this kind of increase of mass, that is to say, of mass intrinsically possessed by the moving body, and not accreted on it from outside stationary matter. The latter effect is familiar in raindrops and in viscosity of gases, and it tends to reduce relative motion; but no previous instance is known where the mass of the moving body rises because it is itself a function of velocity. It would seem that the momentum must increase, and must disturb the balance of forces holding the parts of the system together. In an extreme case it might happen that the lighter body would suddenly become the heavier, would behave as if it had encountered an obstacle, and would jerk the rest of the atom off; or, on the other hand, it might happen that the most rapidly moving portion itself, by reason of its sudden access of momentum, would break loose and proceed tangentially. In any case it appears likely that an atom at this stage would begin to break up, as observed experimentally by Rutherford and Soddy; in other words, the fact of electronic radiation seems to carry with it the liability to change or decay of all matter possessing an electric constitution; the change from one form to another being accompanied, as they demonstrate in many cases, by radio-activity—a phenomenon which Strutt finds widely diffused.

It is hardly necessary to direct attention to a sort of astronomical analogy to this, though governed by different forces, in the contracting or gradual collapsing of a nebula, with the occasional shrinking off of peripheral material as an unstable stage is periodically reached, in accordance with the rough approximation known as Bode's law, together with the strong radioactivity of the central mass, and the conversion of constitutional potential energy into heat.

A few more words on the increase of mass at the critical velocity:—The only expression for mass as depending on velocity which has met with any attempt at experimental verification, is the expression of Abraham supposed to be verified by Kaufmann by direct experiment on curvature of kathode rays. Taking this as a simple example of the kind of effect to be expected, viz.

$$\frac{m}{m_0} = \frac{3}{4\beta^2}\left(\frac{1+\beta^2}{2\beta}\log\frac{1+\beta}{1-\beta} - 1\right) \quad . \quad . \quad . \quad . \quad (5)$$

where β is the ratio u/v, the speed of an electric particle to that of light, and m_0 its ordinary purely electric mass for slow motions, we find that when an electron is moving with *half* the speed of light, its mass is only 1.12 times what it was when stationary. At *three-quarters* of the speed of light the mass ratio becomes 1·37, or little more than a third greater than its normal value. At *nine-tenths* of the light velocity the mass is still not doubled, being only 1.8 times m_0.

When within 1 per cent. of the light speed the mass is trebled, or, more exactly, multiplied by 3·28, and when within one part in a thousand of its limiting velocity, the mass is almost exactly quintupled.

For higher speeds, say within $1/n$th of the speed of light, or $u=(1-1/n)v$, n being great, the expression for the electric mass ratio simplifies to

$$m = \frac{3}{4}\left\{\log(2n-1) - 1\right\}m_0 \quad . \quad . \quad . \quad . \quad (6)$$

which ultimately is truly infinite, but for even excessive values of n is only moderately great.

It is notable how close to the velocity of light it is necessary to get before this effect becomes prominent; the instability must be expected to arrive sharply whenever the velocity of light is from any cause, *e.g.* perturbation or collision, attained by any moving electrically charged part of an atom. Assuming a Maxwell distribution of velocities and an average speed, for the internal atomic motions, it may be possible (as J. J. Thomson suggested in NATURE of April 30, p. 601) to calculate what percentage of a given number of atoms reach the unstable stage by this means, and so to make a theoretical estimate of the amount of radioactivity to be expected, and of the life of an atom. But the slight constant radiation-loss seems competent to bring about instability and decay irrespective of collisions, and therefore independently of any Maxwell-Boltzmann law.

OLIVER J. LODGE.

PHOTOGRAPHS OF SNOW CRYSTALS.

AT the beginning of last year (vol. lxv. p. 234) we summarised a paper contributed by Mr. W. A. Bentley to the U.S. *Monthly Weather Review* upon his photomicrographs of snow crystals. Mr. Bentley has made a study of the forms of snow crystals for more than twenty years, and has obtained a most valuable collection of photomicrographs taken with the object of discovering the connection between characteristic forms and particular meteorological conditions. During the winter of 1901–1902 a systematic record was secured by Mr. Bentley of a number of snow storms, and several good photomicrographs from each storm were obtained by him, more than two hundred pictures being added to his collection. The annual summary of the *Monthly Weather Review* for 1902 (vol. xxx. No. 13), which has just been received, contains reproductions of these photomicrographs and a paper by Mr. Bentley describing the various types of structure and the meteorological conditions prevailing at the time when they were produced. The paper contains an instructive account of snow crystals, and an analysis of the results of the studies carried on during the winter of 1901–1902. The interest of the pictures lies not merely in the fact that many of the forms photographed are very remarkable, but that they also represent, so far as possible, stages in the life-history of snowstorms, several pictures having been obtained of each storm, while at the same time a record was kept of the conditions of temperature, pressure, wind, cloud and position of storm from which the snow fell.

We print a few extracts from the contribution and reproduce several photomicrographs of exceptional interest from those given in the *Monthly Weather Review.*

> In general the data tend to confirm further the conclusions of all observers, that a more or less intimate connection exists between form and size of nuclei, and the altitude and temperature of the air in which the crystals form. There can be no longer any doubt that there is a general law of distribution of the various types of crystals throughout the different portions of a great storm. On this point the data secured, both by direct observation and by a study of the weather maps, are much more complete and satisfactory than has hitherto been published. This aspect of our study received special consideration, because it was thought to be most important.
>
> Snowstorms often cover a region of vast extent; crystallisation is going on within them over nearly the whole area, and therefore in regions that differ greatly among themselves as to temperature, humidity, air density, electrical conditions, &c. Moreover, the kind, number, dimensions, altitude and density of the clouds within those various regions differ so greatly one from another that the snow crystals emanating from each region furnish us rare opportunities for observing and studying the effects of each of these various conditions upon the forms.

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